REMARKS

Upon entry of the above amendment, Claims 1-13, 21, and 23-28 are currently pending.

In the above amendments, claims 1 and 23 have been amended to recite that the barrier film feature of the claimed invention comprises barium atoms in "elemental" form (see, e.g., specification, page 25). Claim 23 also has been amended to recite that the barrier film has a thickness ranging from approximately 5-100 Å and that the substrate is a semiconductor material (specification, pages 7, 34). New claims 24 and 26 recite a barrier film thickness supported by the specification (e.g. page 34; Ex parte Jackson, 110 USPQ 561-562 (PTO Bd. of Appeals 1956)(added claim range of "4% to 20%" held supported by original data points of 4%, 15%, and 20%; In re Wertheim, 191 USPQ 90, 98 (CCPA 1976)). New Claims 25, 27 and 28 are supported, for example, by instant Figure 3. Editorial changes have been made to other claims. No new matter has been introduced.

Response to Anticipation Rejections:

A. At pages 2-3 of the Office Action, claim 23 has been rejected under 35 U.S.C. § 102(a) as being anticipated by U.S. Pat. No. 5,677,572 to Hung et al. Applicants respectfully traverse.

The Office Action is understood to urge, among other things, that Hung et al. disclose: "*a substrate (11); a barrier film (13a) comprising barium atoms having a thickness less than 100Å on the substrate; a material (13b) on the barrier film. Note Figure 1 of Hung et al.*"

Applicants point out that the present invention, as recited in current claim 23, relates to a semiconductor device including a barrier film comprising an *elemental* layer of barium atoms having a thickness ranging between approximately 5-100Å on a substrate, and a metallic material on the barrier film. A metal, such as barium, when defined as being in "elemental" form, as that terminology is customarily and ordinarily understood and defined by a person of ordinary skill in the art of interest, implicitly and inherently denotes a metal that is in a free and unoxidized state, which excludes a compound or salt form thereof. This convention in terminology is well-accepted and understood in the field, such as illustrated by reference to the prior art patent literature.[1]

The present invention offers the advantage of providing an extremely thin barrier film that nonetheless is effective to inhibit diffusion of materials such as conductors, especially metallic materials such as copper (i.e., pure copper, copper alloys, doped copper, and so forth) into adjacent semiconductor substrates.

By contrast, Hung et al. does not describe a layer of "elemental" barium atoms provided between a substrate and a separate metallic layer. Instead, Hung et al. instead describes a thin "non-conducting" (i.e., electrically insulating) layer 13a as being comprised of alkali or alkaline earth fluorides or oxides, including barium fluoride or barium oxide, *inter alia* (see col. 2, lines 53-63), as provided between an n-type semiconductor substrate 11 and a thick conductive layer 13b.

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1 E.g., see col. 2, lines 64-65 of U.S. Pat. 5,677,572 to Hung et al. of record ("elemental metal"); & Claims 2-3 are reproduced below from U.S. Pat. 5,753,040 of record (Applicants' emphasis added by underlining):

2. The method of claim 1 wherein said epitaxial metal is an <u>elemental</u> metal.

3. The method of claim 2 wherein said <u>elemental</u> metal is aluminum.

The background section in Hung et al. indicates an objective in the field of metal-semiconductor contacts is the reduction of barrier height to electron flow or transport relative to an n-type semiconductor (which in turn reduces barrier resistance and power consumption)(col. 1, lines 19-42). Hung et al. are understood to hypothesize that it might be desirable to try to make the electrode itself from metals with a low work function (e.g., lithium, sodium, potassium, rubidium, barium, magnesium, calcium, strontium and barium), but then indicates and represents that these metals per se are not suitable because they are "chemically reactive and are susceptible to atmospheric oxidation and corrosion" (col. 1, lines 41-47).

Consequently, the actual invention of Hung et al. is premised on a bilayer electrode 13 comprised of a thin non-conducting, insulating layer 13a, provided between an n-type semiconductor substrate 11 and a thick conductive layer 13b (col. 2, lines 15-23, 48-52). In this regard, Hung et al. makes it unequivocally clear that the non-conducting layer 13a is selected as an alkali or alkaline earth metal fluoride or oxide compound to provide an insulating material with high bandgap energy and strong dipole character, which when interposed between the conductive layer 13b and the n-semiconductor substrate 11, enables the reductions in barrier height for electron transport to be realized (col. 2, lines 15-23; col. 4, lines 29-37).

In contrast to Hung et al., the present claimed invention is not concerned with reducing barrier height to electron flow or transport relative to an n-type semiconductor. The present invention, instead, is concerned with providing an atomic migration barrier function relative to an adjoining and separate metallic layer. In the present invention, such as recited in claim 23 (and

also claims 1, 2), the barrier film comprises elemental barium atoms, and *not* fluoride and oxide compounds of barium having strong dipole character.

Therefore, if anything, Hung et al. only teaches away from the present invention.

Again, Hung et al. does not describe each and every element set forth in amended claim 23, requiring "a barrier film comprised of elemental barium atoms", *inter alia*. Therefore, Hung et al. does not meet the legal requirements for anticipation relative to amended claim 23.

In view of the above, Applicants respectfully submit that Hung et al. does not does not defeat the patentability of the present claims, and, accordingly, this rejection should be withdrawn.

B. At page 3 of the Office Action, claim 22 has been rejected under 35 U.S.C. § 102(a) as being anticipated by U.S. Pat. No. 5,962,921 to Farnworth et al.

Applicants submit that this rejection has been rendered moot by the cancellation of claim 22.

Response to Obviousness Rejections:

A. At pages 3-4 of the Office Action, claims 1 and 21 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Hung et al. Applicants respectfully traverse.

Among other things, this rejection states that:

> Hung et al. does not clearly disclose the barrier film is a monolayer. However, in column 3, lines 3-6, Hung et al. discloses the thickness of the barrier film is between 0.3 to 5.0 nm. Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to consider the barrier film of Hung et al. as a monolayer.

Office Action, page 4.

Again, Applicants point out that non-conducting layer 13a of Hung et al.'s bilayer electrode is NOT a "barrier" film, contrary to what is suggested in the above-reproduced Office Action remarks. As pointed out above, the function of alkali or alkaline earth metal fluoride or oxide non-conducting layer 13 of Hung et al. is that its strong dipole character can be used *to reduce the barrier height for electron transport* in the device (col. 4, lines 29-37).

Instant Claims 1 and 21, among other things, recite that the a barrier film is comprised of or comprises elemental barium atoms, which excludes barium compounds such as barium fluoride or barium oxide. Hung et al. is clearly distinguished on this basis.

Therefore, Hung et al., standing alone does not render obvious the invention as recited in either of instant claims 1 or 21.

B. At pages 4-6 of the Office Action, claims 1-13 and 21-23 have been rejected under 35 U.S.C. § 103(a) as being unpatentable over Farnworth et al. or U.S. Pat. No. 5,285,079 to Tsukamoto et al. in view of Hung et al. Applicants respectfully traverse.

Contrary to the indication made in the Office Action, Applicants point out that Farnworth et al. describe an insulating layer 36, and not the substrate 30, upon which a conductive layer 34 is applied. That is, Farnworth et al. describe providing the insulating layer 36 in-between the substrate 30 and the conductive layer 34 (see Fig. 3), and the conductive layer 34 does not directly contact the silicon substrate 30 (unlike the requirements of instant claims 25, 27-28, for example).

Additionally, the conductive layer "34", as actually described by Farnworth et al., is never characterized as being a "barrier" film much less one against atomic migration from the solder bump material 12 to the substrate 30 (col. 6, line 39 to col. 8, line 17). Instead, Farnworth et al. merely includes barium (Ba) among some 29 possible alternative metals and alloys thereof (not to mention the metal silicides, metal nitride and metal boride additionally mentioned) as proposed for conductive layer 34. Elemental barium per se is never identified nor exemplified by Farnworth et al., nor does Farnworth et al. ever describe the formation thicknesses of the conductive layer 34 as used in the solder bump interconnection structure of Farnworth et al. (see col. 7, lines 54-57; col. 8, lines 1-17).

The fact that the conductive layer 34 is not defined by Farnworth et al. as an atomic migration barrier film in purpose or in practice is highlighted by the fact that Farnworth et al. teach

that the solder bumps 12 are made of a *lead/tin* alloy (col. 4, lines 51-52; col. 1, lines 24-26), and NOT copper or other types of metals such as described in the instant specification having a tendency to diffuse into silicon or other semiconductor substrates (e.g., compare to instant claims 2, 13).

Additionally, Applicants have reviewed U.S. Pat. No. 5,607,818, which is cited by Farnworth et al. at col. 8, lines 4-7 therein, as purportedly providing descriptions on how to "plate" or "metallize" some of the materials listed in the Farnworth et al. patent, including barium supposedly, in providing conductive layer 34. Based on this review, it is apparent that U.S. Pat. No. 5,607,818 relied upon by Farnworth et al. nowhere mentions barium, much less provides any enablement on how to "plate" or "metallize" barium in elemental form on a substrate, much less in thin thickness of less than approximately 100Å, nor how to plate it on a substrate so that it might be suitable for attaching lead/tin solder bumps in an interconnect structure such as taught by Farnworth et al.[2] By contrast, the instant specification clearly describes several processing protocols for successfully forming a very thin elemental barium barrier film directly on a semiconductor substrate (pages 23-25).

As to the other primary reference relied upon in the rejection to Tsukamoto et al., it is noted that it generally concerns an electron emitting device. Applicants disagree with the characterizations made at page 5 of the Office Action of the teachings of the Tsukamoto et al. reference.

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2 **A prior art publication must be sufficiently enabling in order to place the allegedly disclosed subject matter in the public's possession. <u>In re Epstein</u>, 31 USPQ2d 1817, 1823 (Fed. Cir. 1994).**

First of all, Tsukamoto et al. does not teach the provision of any *barrier* film, much less one that functions to inhibit diffusion of a conductor into a semiconductor substrate. Secondly, to the extent Tsukamoto et al. teaches collector layer 105 comprises a semiconductor *and* barium or barium oxide (col. 3, lines 63-66), that reference elsewhere clearly indicates that the barium is *applied onto the surface areas where electrons are to be emitted* (col. 4, lines 38-44). As seen in Figure 1 of Tsukamoto et al., the electrons (e^-) are emitted in the *exposed* area of collector 105 defined by the channel shaped region located laterally *between* ohmic contact electrodes 106.

Tsukamoto et al. nowhere teaches or depicts providing an elemental barium film as positioned vertically between the ohmic contact electrodes 106 and the uppermost flat surfaces of collector 105. This is not surprising from a processing and practical standpoint. As can be appreciated, the channel formation step for layer 105 necessarily proceeds any barium deposition thereon. It can be easily deduced that the electrodes 106 are formed first on a flat-surfaced (non-channeled) collector layer 105, and thus before any deposition of any barium onto layer 105, because Figure 1 indicates the electrodes 106 form at least part of the mask used during formation of the channel feature in layer 105. That is, the locations of the channel walls clearly are defined by the inner lateral sides of the ohmic electrodes 106. Figure 1 clearly shows that the ohmic electrodes 106 delimit the lateral dimensioning of the channel formed in layer 105. Hence, the only logical answer to be drawn from these facts in Tsukamoto et al. itself is that the ohmic electrode 106 formation proceeded the deposition of any barium onto the channel area of collector layer 105. Consequently, no barium would be present directly between the ohmic electrodes 106 and any semiconductor portions of collector 105. This

understanding of the teachings in Tsukamoto et al. regarding how barium, or the alternatively referenced cesium or cesium oxide (col. 3, lines 63-66), is deposited in these semiconductor electron emitter devices is confirmed by cross-reference to cumulative semiconductor emitting device prior art recently cited along with Tsukamoto et al. in Applicants' co-pending U.S. application serial no. 09/137,086. Namely, U.S. Pat. Nos. 6,064,074 to Van Zutphen et al. and U.S. Pat. No. 3,931,633 to Shannon et al. teach that cesium or cesium oxide provided for lowering electron work function on the surfaces of a substrate in an emitting device must be located in an exposed manner and laterally adjacent, and not under, the metal layer portions of the emitting device.

Therefore, Tsukamoto et al. does not teach, suggest or implicitly require that the "conductor" 106 is located *on* the barium, cesium, or cesium oxide surface portions of collector 105.

The Office Action does not suggest a technical theory or identify any facts from the Tsukamoto et al. which would support a proposition that Tsukamoto et al. might teach, suggest or enable any provision of elemental barium directly between the ohmic electrodes 106 and any semiconductor portions of collector 105, as opposed to limiting the presence of the barium to the exposed channel areas in collector 105 as was done by Shannon et al. Nor does the prior art of record indicate or suggest that an "ohmic contact electrode" formed on a semiconductor body can accommodate or should incorporate an elemental barium layer at the interface of the semiconductor material and the contact electrode material.

The Office Action (at page 5) asserts that it would have been obvious to form the conductive "barrier film" of Farnworth et al. or Tsukamoto et al.'s devices as a monolayer, in view of the

purported teachings in Hung et al. that it such would "reduce the work function between the semiconductor substrate and a metal electrode".

In response, Applicants reiterate that Hung et al., if anything, teaches away from the present invention. Again, Hung et al. specifically teach against attempting to form the contact electrode from pure alkali or alkaline earth metals (col. 1, lines 29-47). Hung et al. actually teach the necessity of a bilayer design electrode including a non-conducting layer 13a formed of alkali or alkaline earth metal fluorides or oxides having a strong dipole character formed between the surface of the n-type semiconductor and an overlying conductive layer, in order to attain the desired reductions in barrier height for electron transport (e.g., col. 2, lines 15-18; Example 4, col. 6, lines 30-37).

Therefore, it is not apparent how it would have been obvious to one of ordinary skill to consider providing a monolayer or layer of elemental barium atoms for conductive layer 34 of Farnworth et al. or at the surface of collector 105 below "conductor" 106 of Tsukamoto et al. based on anything learned from Hung et al. In fact, since Hung et al. requires an insulating, non-conducting oxide or fluoride compound material having a strong dipole character for layer 13a, the introduction of layer 13a of Hung et al. for some layer in the devices described by either Farnworth et al. or Tsukamoto et al., for sake of argument only, would lead away from the present invention requiring, inter alia, a barrier film comprising *elemental* barium atoms films.

Also, none of the relied upon prior art in this rejection teaches and suggests that elemental barium can inhibit atomic migration of metals such as copper in which the elemental barium is

provided in very thin film thicknesses of less than 100Å (instant claim 3), or not more than approximately only 20Å (instant claim 4), or not more than approximately 5Å (instant claim 5), or a thickness ranging only from approximately 5-100Å (claim 23) or only approximately 5-20Å (instant claims 24, 26). Moreover, the relied upon prior art provides no enablement for one of ordinary skill in the art on what processing protocol might be used to achieve such extremely thin thicknesses in an elemental barium layer, much less for an atomic migration barrier implementation in particular. For instance, Farnworth et al. (col. 8, lines 5-7) relies upon U.S. Pat. No. 5,607,718 for illustrations on how the conductive layer 34 might be formed, but U.S. Pat. No. 5,607,718 (as with Farnworth et al.) does not exemplify barium film formation and only teaches conductive layer (16) thicknesses of 500Å to about 10 μm (col. 6, lines 13-14). Also, instant claim 2 in particular explicitly recites the atomic migration barrier properties possessed by the barrier film feature of the inventive semiconductor device.

In response to the remarks made at the top of page 6 of the Office Action, Applicants reiterate that none of the relied upon prior art in this rejection suggest the suitability of thin films of elemental barium as an atomic migration barrier against copper metal. To allege that a "known material" has "suitability" for a given purpose in a conclusory manner, as done in the first paragraph at page 6 of the Office Action, merely begs the question of whether that particular suggestion comes from the state of the art or only Applicants' own patent specification? A proper prima facie case of obviousness cannot be premised on the latter situation. That is, Applicants point out that obviousness cannot be established by combining or modifying the teachings of the prior art to produce the claimed invention, absent some teaching,

suggestion or incentive supporting the combination or modification. *ACS Hospital systems, Inc. v. Montefiore Hospital*, 221 USPQ 929, 933 (Fed. Cir. 1984). Moreover, *the prior art items themselves* must suggest the desirability and thus the obviousness of making the combination or modification without the slightest recourse to the teachings of the application; without such independent suggestion, the prior art is to be considered merely to be inviting experimentation which is not the standard with which obviousness is determined. *In re Laskowski*, 10 USPQ2d 1397, 1398 (Fed. Cir. 1989). That is, the test under 35 USC §103 is not what "one might contemplate," but rather whether the reference(s) would have actually suggested the invention to one of ordinary skill in the art. *Medtronic Inc. v. Cardiac Pacemakers, Inc.*, 220 USPQ 97 (Fed. Cir. 1983); *In re Fine*, 837 F.2d 1071, 1075, 5 USPQ2d 1596, 1599 (Fed. Cir. 1988) ("whether a particular combination might be 'obvious to try' is not a legitimate test of patentability").

Therefore, one of ordinary skill in the art would have found no bona fide motivation or reason from the teachings of Farnworth et al. or Tsukamoto et al. to consider providing very thin elemental barium films that nonetheless have atomic migration barrier properties in semiconductor devices.

In view of the above, Applicants respectfully submit that the proposed combination of Farnworth et al. or Tsukamoto et al. in view of Hung et al. does not defeat the patentability of the present claims, and, accordingly, this rejection should be withdrawn.

Should no other rejections or objections remain outstanding, Applicants submit that this present application is in condition for allowance and earnestly request notification of same.

If the Examiner believes that a teleconference would be useful in expediting the prosecution of this application, the official is hereby invited to telephone the undersigned counsel to arrange for such a conference.

Respectfully submitted,

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